UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

DTIC FILE COPY

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS --
2a. SECURITY CLASSIFICATION AUTHORITY -	3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. I -	
4. PI - **AD-A226 331**	5. MONITORING ORGANIZATION REPORT NUMBER(S) -- AFOSR-TR- 90 0876
6a. NAME OF PERFORMING ORGANIZATION The Regents of the Univ. of California, San Diego	6b. OFFICE SYMBOL (If applicable) --
7a. NAME OF MONITORING ORGANIZATION Air Force Office of Scientific Research/NL	
6c. ADDRESS (City, State, and ZIP Code) University of California, San Diego 9500 Gilman Drive La Jolla, CA 92093	7b. ADDRESS (City, State, and ZIP Code) Bldg. 410, Bolling Air Force Base D.C. 20332-6448
8a. NAME OF FUNDING / SPONSORING ORGANIZATION AFOSR/NL	8b. OFFICE SYMBOL (If applicable) NL
9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER AFOSR 89-0456	
8c. ADDRESS (City, State, and ZIP Code) Bldg. 410 Bolling Air Force Base, D.C. 20332-6448	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. 61102F; PROJECT NO. 2313; TASK NO. A4; WORK UNIT ACCESSION NO. --

11. TITLE (Include Security Classification)
Comparative Analytical Study of Evoked and Event Related Potentials as Correlates of Cognitive Processes

12. PERSONAL AUTHOR(S)
Bullock, Theodore H. and Basar, Erol

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final Technical	FROM 8/1/89 TO 7/31/90	90/07/16	

16. SUPPLEMENTARY NOTATION

1990

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP
05	09	--

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Electroencephalogram
Event related potentials
Evoked potentials

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This project is a collaboration between the two named laboratories, extending the capabilities of each group. It combines the analytical approach of multielectrode recording from many places in the brain with the comparative approach of seeking clues from lower animal species. Using selected paradigms of stimulus presentation or omission already known to trigger Event Related Potentials (ERPs) in humans, as well as mental events, this program compares brain recording from cats, reptiles, fish and other lower models, analyzing both single trials and averages from many channels. Sacrificing the advantage of human subjects easy to instruct and to control with respect to attention, we can go farther in number of intracranial electrodes in deep cerebral and brainstem loci. Early results show that lower species have ERPs by the definition of the stimulus regime and that much of this response occurs at lower brain levels, probably precognitive, suggesting the need to distinguish the components in humans that depend on cognition from those that do not. New forms of grading the expectation of stimuli are being compared on humans, cats, and lower species.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION
☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS	Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code)	22c. OFFICE SYMBOL
Alfred R. Fregly	(202) 767-5021	NL

DD FORM 1473, 84 MAR 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

90 08 28 084

24 JUL 1990

FINAL SCIENTIFIC REPORT
ON RESEARCH PROJECT CONDUCTED UNDER AFOSR GRANT

AFOSR-89-0456, BSC

"Comparative Analytical Study of Evoked and Event Related Potentials as Correlates of Cognitive Processes"

by Theodore H. Bullock and Erol Başar
Department of Neurosciences, University of Calif., San Diego and
Physiological Institute, Medical University, Lübeck, FRG

Abstract

This project is a collaboration between the two named laboratories, extending the capabilities of each group. It combines the analytical approach of multielectrode recording from many places in the brain with the comparative approach of seeking clues from lower animal species. Using selected paradigms of stimulus presentation or omission already known to trigger Event Related Potentials (ERPs) in humans, as well as mental events, this program compares brain recording from cats, reptiles, fish and other lower models, analyzing both single trials and averages from many channels. Sacrificing the advantage of human subjects easy to instruct and to control with respect to attention, we can go farther in number of intracranial electrodes in deep cerebral and brainstem loci. Early results show that lower species have ERPs by the definition of the stimulus regime and that much of this response occurs at lower brain levels, probably precognitive, suggesting the need to distinguish the components in humans that depend on cognition from those that do not. New forms of grading the expectation of stimuli are being compared on humans, cats, and lower species.

Introduction and Rationale

Little is known about the basic mechanisms of Evoked Potentials (EPs) and Event Related Potentials (ERPs) - known to be useful objective signs of signal processing and cognitive events in the brain, especially their distribution in the brain, relation to ongoing EEG, dependence on cognition, and uniquely human attributes (Başar 1988; Başar and Bullock 1989 and extensive literature referenced in the original proposal, dated April 7, 1989). In view of the unexpected character of the evolution of ongoing compound field potentials (micro-EEG) of the brain, especially the cortex (Bullock and Başar 1988; Bullock 1988a), and of the comparative neurology of expectation (Bullock 1988b), it appears likely that new insights could be gained by examining whatever signs can be found during administration to lower animal models of the applicable stimulus regimes from among those that have been used on human subjects. Initial results from experiments on rays and teleosts have been reported (Bullock et al. 1990).

Plan of the Collaboration

The present project was planned to take advantage of the mutual interest and complementary facilities of the two PIs named in the heading. Başar and Bullock can collaborate to some extent by mail, telephone and fax - and have done so extensively in the past. However, this does not realize the potential of the collaboration because each laboratory is the best place to do certain experiments and analyses.

Research Conducted

The plan outlined in the proposal had to be curtailed in time. Bullock had to cancel his trip scheduled for September-October, 1989 at the last minute because of his wife's health and the next opportunity to spend time in Lübeck came in May, 1990, for only 10 days.

After extensive collaboration by mail and wire, a very intensive working period was spent in the laboratories of Başar in Lübeck between May 2nd and 13th. The experiments had been carefully planned, many preparations had been made, everything was ready and worked smoothly, a large part of the staff of the laboratory was involved. This included, in addition to the two P.I.s, Dr. Canan Başar, Dr. Tamer Demiralp, Dr. Martin Schürmann, Dr. Elke Rahn, the engineer Ferdinand Greischutz, and the technician.

Among the significant accomplishments were protracted discussion of old data, examination and evaluation of new data, recently gathered by each of the scientists named above, and discussion of important priorities for future research. A new book on a currently hot topic, "Induced Rhythms in the Brain", to be co-edited by the two P.I.s was outlined in detail and some 20 authors of contributed chapters were recruited by telephone, all agreeing to submit their chapters by the end of August, 1990, just 3 1/2 months away. A publisher was selected and has agreed to take on the project.

Experiments were carried out all day every day, about equally divided between those upon trained human subjects (the above named postdoctoral associates) and those upon cats previously surgically implanted with an array of electrodes in the strategic parts of the brain, by Dr. Canan Başar. As a result many tens of megabytes of data are now stored in the computer. The continuous ink records have been scrutinized and those epochs with eye blinks and similar bad places selected out. Many dozens of graphs have been computed, and plotted, in color, both as average potential at each electrode, before and after the target time and as transfer functions of the first derivatives in the chosen band for the period after the target. Tapes of data and printouts of plots and graphs have been exchanged since Bullock returned from the period in Lübeck, and new analyses and plots have been specified to be done on the stored data.

The experiments and the data gathering, for which the agenda-protocol is attached, explaining the exact design of each experiment, went smoothly and in that sense were successful. Not all eight experiments were accomplished in full but major portions of each of them. The analysis and evaluation is now in progress and will continue for some time.

Preliminary analysis suggests that a paper might be in order reporting on the Event Related Potentials to Omitted Stimuli at different interstimulus intervals (ISIs, 1/flash rates) and degrees of regularity in the cat (passive paradigm) and human (active and passive paradigms). However, if such a publication in a primary journal is determined to be advisable, it will require substantially more data (additional experiments), both to increase the number of instances (subjects and days, with more numerous and shorter recording sessions) and to extend the range of tests to shorter ISIs, to lower probability of targets. Also desireable will be a series of similar experiments with acoustic stimuli.

In the experience of the U.S. partner, the facilities, experience and team available in Lübeck make it uniquely efficient as a place to get such results, both on the human subjects and on cats, which from practical considerations he cannot now study in his own laboratory.

Principal Findings

The principal findings of the experiments during this intensive visit may be summarized as follows. (i) The Event Related Potential (ERP) following a missing stimulus in a regular series has close to the same latency after the omitted stimulus was due, when the conditioning series had different InterStimulus Intervals (ISIs), reinforcing the supposition that the ERP is time-locked to a learned expectation. (ii) The ERP is larger and briefer for more accurately predicted expectations, both those due to regular conditioning series at shorter ISIs and those due to irregular ISIs, jittered around a mean value. (iii) The ERP is much smaller, merging into insignificance, without attention - confirming previous studies. The first two of these findings are probably new for human subjects.

Attached Appendices

The following attachments provide detail on three aspects of the results mentioned above. (i) The agenda-protocol, dated 05-03-90, for the experiments just conducted. (ii) Sample plots of three experiments on one human subject (Figure 1), with a legend that details the experimental conditions as well as the significant questions posed and answered by those examples. (iii) A list of authors of chapters for the book "Induced Rhythms of the Brain" now in preparation by these authors, to be edited and integrated by the PIs of the present grant.

References

Başar, E. 1988. *Dynamics of Sensory and Cognitive Processing by the Brain*, E. Başar, ed., Springer-Verlag, Berlin.

Bullock, T.H. 1988a. Compound potentials of the brain, ongoing and evoked: perspectives from comparative neurology. In: *Dynamics of Sensory and Cognitive Processing by the Brain*, E. Başar, ed., Springer-Verlag, Berlin, pp. 3-18.

Bullock, T.H. 1988b. The comparative neurology of expectation: stimulus acquisition and neurobiology of anticipated and unanticipated input. In: *Sensory Biology of Aquatic Animals*, J. Atema, R.R. Fay, A.N. Popper, W.N. Tavolga, eds., Springer-Verlag, New York, pp. 269-284.

Bullock, T.H., Başar, E. 1988. Comparison of ongoing compound field potentials in the brains of invertebrates and vertebrates. *Brain Res. Rev.*, 13:57-75.

Başar, E., Bullock, T.H. 1989. *Brain Dynamics: Progress and Perspectives*, Springer-Verlag, Berlin.

Bullock, T.H., Hofmann, M.H., Nahm, F.K., New, J.G., Prechtl, J.C. 1990. Event related potentials in the retina and optic tectum of fish. *J. Neurophysiol.* (In press)

Theodore H. Bullock

Erol Başar

July 17, 1990

file: memo.503 rev. 05-03-90

PROPOSED PROTOCOL FOR CAT OSP EXPERIMENTS

-Recording at cortical, hippocampal, reticular, tectal and inferior colliculus sites.
-Band-width 0.3-100 Hz.
-Stimulate with flash trains of duration = D, flash frequency = F, rest period = R, number of trials = N.
-Triggers for averaging on first flash and on last flash. Save specified pretrigger time and posttrigger time - normally store 1 s before and 1.5 s after trigger = 2.5 s total, per trial.
-Reject bad epochs (large deflections).
-Subject awake, resting quietly.
-Flash and room light parameters to be tested and selected to give not quite maximal (saturated) VEP in both tectum and visual cortex.

Exp. 1: Standard experiment. D=10s; F=5 Hz; R=10s; N=30

Exp. 2: Short duration tests. Same as Exp. 1, but D=1s; 3s.

Exp. 3: Mid-frequency series. Same as Exp. 1, but F = 1, 2, 3, 4, 6, 7.5, 10 Hz, plus steady light (or >100 Hz).

Exp. 4: Low frequency tests. If 1 Hz gave a detectable OSP, F=0.5, 0.3 Hz.

Exp. 5: High jitter experiment. Same as Exp. 1, mean interval = 200 ms, but intervals are jittered from 100 - 300 ms, pseudo-randomly so that mean = 200; the last interval = 200 ms; successive trials are congruent = exact sequence of intervals is repeated.

Exp. 6: Low jitter experiment. Same as Exp. 5 but jitter from 150-250 ms.

Exp. 7: High frequency series. Same as Exp. 1 but F = 15, 20, 25, 30 Hz Repeat only 4 times (N = 4), since these are not to be averaged but printed as single sweeps, closely spaced, under each other, with hidden line suppression. This experiment is desireable if a VEP is visible in any electrode, on single sweeps. It is to examine the UFF = Upper Following Frequency - the highest frequency permitting 1:1 following; this does not allow averaging since that could fill in missing cycles on successive sweeps. Hence, it requires VEPs well visible on every sweep.

Exp. 8: Human series. Do as much as possible of Exps. 1-6 with human scalp recording. Exp. 7 is desireable if VEP is visible on single sweeps.

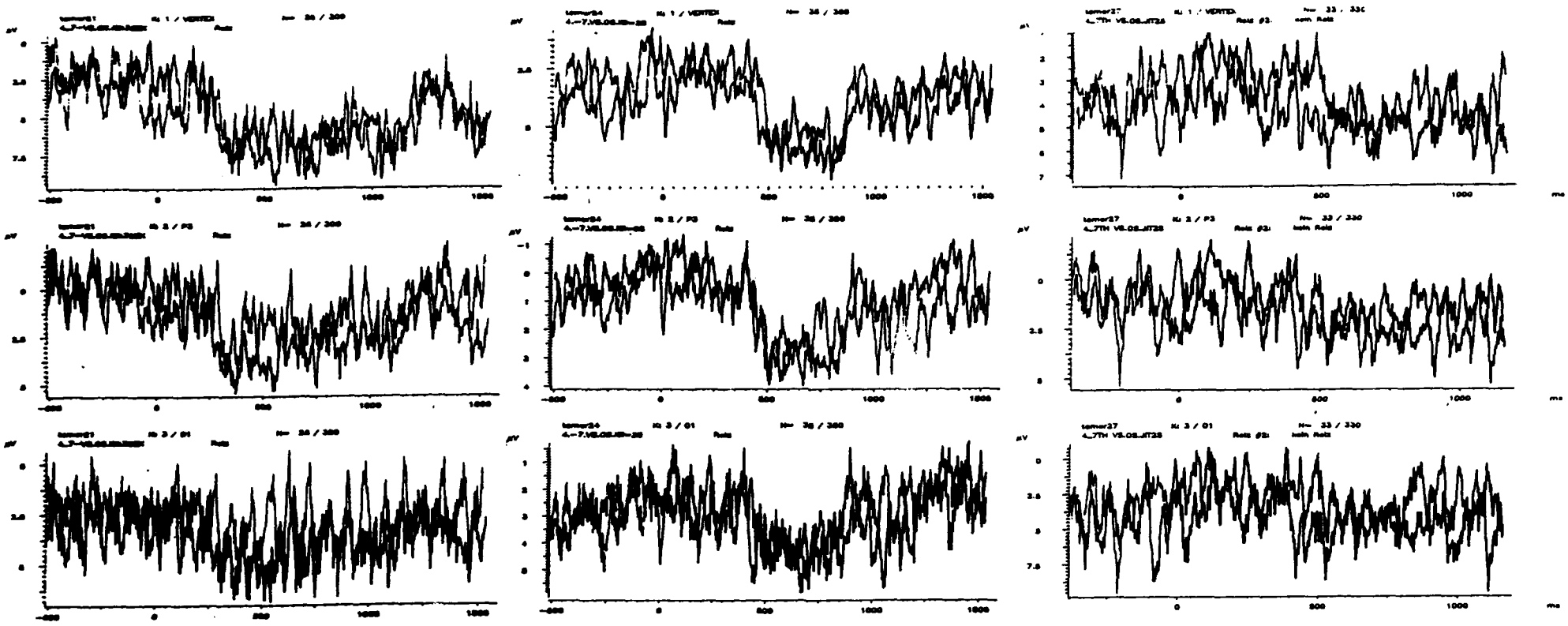

Figure 1. An experiment on human Event Related Potentials time-locked to expected but omitted stimuli. The expectation is manipulated by (1) changing the interstimulus interval (ISI) from 3 s to 2 s, and (2) by changing the regularity of the ISI from regular to jittered.

(1) If the ERP is a sign of expectation time-locked to the prediction of a stimulus, it should remain at the same latency after the omitted stimulus was due. Note the positive deflection is within ca. 100 ms equal but slightly later as well as sharper and shorter for 2 s than for 3 s.

(2) If the ERP is a sign of expectation time-locked to the prediction of a stimulus, it should suffer some delay and uncertainty of timing, presumably therefore attenuation of the average, when the ISI is jittered. Note the results also conform to this anticipation.

Contributors 7/90 - "Induced Rhythms of the Brain"

W. Ross Adey
Pettis Memorial Veterans' Hospital
11201 Benton Street
Loma Linda, CA 92357 USA
Tel: 714-825-2333

Erol Başar
Institut für Physiologie
Medizinische Universität Lübeck
Ratzeburger Allee 160
D-2400 Lübeck FRG
Tel: 451-500-4170
[Fax: 451-500-3016]

Theodore H. Bullock
Department of Neurosciences 0201
University of California, San Diego
9500 Gilman Drive
La Jolla, CA 92093-0201 USA
Tel: 619-534-3636
[Fax: 619-534-0784]

Györgyi Buzsáki
Department of Neurosciences 0624
University of California, San Diego
9500 Gilman Drive
La Jolla, CA 92093-0624 USA
Tel: 619-534-1377
(Will move to Rutgers Univ. 9/90)

Reinhard Eckhorn
Institut für Angewandte Physik und Biophysik
Universität Marburg
Renthof 7
D-3440 Marburg FRG
Tel: 6421-284164

Walter Freeman
Department of Physiology-Anatomy
University of California, Berkeley
Berkeley, CA 94720 USA
Tel: 415-642-4220

Robert Galambos
8826 La Jolla Scenic Drive North
La Jolla, CA 92037 USA
Tel: 619-453-0151

Albert Goldbeter
Faculté des Sciences
Université Libre de Bruxelles
Campus Plaine, C.P. 231
1050 Bruxelles
Belgium
Tel: 26-40-0015 x5772
[Fax: 26-49-8774]

Charles Gray
Salk Institute for Biological Studies
P.O. Box 85800
San Diego, CA 92138-9216 USA
Tel: 619-453-4100 x158

Herrmann Haken
Institut für Theoretische Physik
Universität Stuttgart
Pfaffenwaldring 57/IV
D-7000 Stuttgart 80 FRG
Tel: 711-685-4989

Stephen Hillyard
Department of Neurosciences 0608
University of California, San Diego
9500 Gilman Drive
La Jolla, CA 92093-0608 USA
Tel: 619-534-3797

Fernando Lopes da Silva
University of Amsterdam
Department of Animal Physiology
Kruislaan 320
Amsterdam, The Netherlands
Tel: 20-525-7637
[Fax: 6659125]

George R. Mangun
Department of Psychiatry
Dartmouth Medical School
Pike House
Hanover, NH 03756 USA
Tel: 603-646-8833

Eve Marder
Department of Biology
Brandeis University
Waltham, MA 02115 USA
Tel: 617-736-3140

Helmut Petsche
Institut für Neurophysiologie
- Hirnforschung
Universität Wien
Währinger Str. 17
A-1090 Wien, Austria
Tel: 222-436141

Gerd Pfurtscheller
Department of Medical Informatics
Institute of Biomedical Engineering
Graz University of Technology
Brockmanngasse 41
A-8010 Graz, Austria
Tel: 316-82-1694-0
[Fax: 316-812964]

Knut Saermark
Laboratory of Physics I
Technical University of Denmark
2800 Lyngby
Denmark
Tel: 42-881611

Terry Sejnowski
Salk Institute for Biological Studies
P.O. Box 85800
San Diego, CA 92138-9216 USA
Tel: 619-453-4100 x611

Wolf Singer
Max-Planck-Institut für
Hirnforschung
Deutschordenstrasse 46
D-6000 Frankfurt 71 FRG
Tel: 69-670-4218
[Fax: 69-6704-433]

Olaf Sporns
The Neurosciences Institute
of the Neurosci. Res. Prog.
1230 York Avenue
New York, NY 10021 USA
Tel: 212-570-8975
[Fax: 212-570-7628]

Mircea Steriade
Université Laval
Faculté de Médécine
Québec, Canada
Tel: 418-656-5547

Felix Strumwasser
Marine Biological Laboratories
Woods Hole, MA 02543 USA
Tel: 508-548-3705